



The plan as a cognitive-resource-saving tool: planning and anticipation, examples in aeronautics.

Sami Lini, Pierre-Alexandre Favier, Xavier Servantie, Bruno Vallespir, Sylvain Hourlier

► To cite this version:

Sami Lini, Pierre-Alexandre Favier, Xavier Servantie, Bruno Vallespir, Sylvain Hourlier. The plan as a cognitive-resource-saving tool: planning and anticipation, examples in aeronautics.. 2012. hal-00675426

HAL Id: hal-00675426

<https://hal.science/hal-00675426>

Preprint submitted on 1 Mar 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

**The plan as a cognitive-resource-saving tool: planning and anticipation,
examples in aeronautics**

Sami Lini^{1,3,5}

Pierre-Alexandre Favier^{2,3,5}

Xavier Servantie⁵

Bruno Vallespir^{1,4}

Sylvain Hourlier⁵

¹ Université de Bordeaux, Université Bordeaux 1 Technologie,

351 cours de la Libération, 33405 Talence, France.

² Université de Bordeaux, IPB, ENSC,

146 rue Léo Saignat, 33076 Bordeaux, France.

³ CNRS, IMS UMR-5218, équipe CIH/ISCC, Bordeaux,

146 rue Léo Saignat, 33076 Bordeaux, France.

⁴ CNRS, IMS UMR 5218, département LAPS,

351 cours de la Libération, 33405 Talence, France.

⁵ Human Engineering for Aerospace Laboratory (HEAL) – THALES/ENSC,

146 rue Léo Saignat, 33076 Bordeaux, France.

Abstract

In their efforts to break with aircraft assistance, Thales Avionics and the ENSC (Ecole Nationale Supérieure de Cognitique) – through the work carried out within their Human Factors for Aerospace Laboratory (HEAL) – have been investigating HMIs assisting pilots in the anticipation process. The approach is user-centred: the understanding of the cognitive mechanisms underlying the anticipation process allows a context-dependent anticipation model to be devised, which aims at designing an ecological assistance tool for pilots. A possible approach to the anticipation process consists of investigating how cognitive plans are developed. To start with, the concepts of anticipation and planning are reviewed. By comparing their definitions, both concepts can be clearly differentiated and the essential function of a plan can be emphasised. The question of the plan as a means of saving cognitive resources is then addressed. Examples in aeronautics are given. Several relevant surrounding psychological concepts are introduced, pointing out the main features of the plan: hierarchy and deficiency. To conclude, based on the conditions of implementation of the plan, the mechanisms of anticipation are discussed, which are close to the principle of reafference.

Keywords: anticipation, planning, cognitive resource management, plan, literature review, aeronautical psychology

The plan as a cognitive-resource-saving tool: planning and anticipation, examples in aeronautics

In an effort to break with aircraft assistance, a study is conducted on HMIs assisting pilots in the anticipation process. The approach is user-centred: the understanding of the cognitive mechanisms underlying the anticipation process allows a context-dependent anticipation model to be devised, which aims at assisting pilots through an ecological HMI. A possible approach to the anticipation process consists of investigating how cognitive plans are developed.

From definitions of the concepts of anticipation and planning, this literature review will address the question of the plan as a means of saving cognitive resources, from its preparation to its implementation. This review will rely on works in the field of cognitive psychology, mainly those by Amalberti and Hoc, and will insist on their contribution to the field of aeronautical psychology. It will be illustrated with examples taken from both civil and military aviation, in order to point out various kinds of constraints, in particular time constraints.

In this effort, the anticipation process will be specifically contemplated and scrutinised. From the activation to validation of a plan, the literature referenced will highlight a closed-loop mechanism, close to the principle of reafference of von Holst & Mittelstaedt (1950).

Definitions: planning or anticipation?

Even though the term ‘anticipate’ is widely used, it is nonetheless difficult to define it precisely. Its Latin etymology ‘anticipare’ means ‘to take action beforehand, to take the initiative, to take the lead’. It is often confused with the terms ‘predict’,

‘foresee’ and ‘plan ahead’. One idea is common to these concepts: the process is both in the present and in the future.

In psychology, Sutter (1983) defined anticipation as a ‘movement by which man carries his entire being beyond the present into a future, near or far, that is essentially his future’ (p. 5). Even though this definition does not exclusively consider taking action, it elicits the idea of thinking ahead: to anticipate is to represent ourselves and our environment in a process of evolution and adaptation.

In cognitive psychology, Cellier (1996) gave the following definition:

‘An activity consisting of evaluating the future state of a dynamic process, determining the type and timing of actions to undertake on the basis of a representation of the process in the future, and, finally, mentally evaluating the possibilities of these actions. It is dependent on the general purpose assigned to an operator in a dynamic context, which is to keep the process, physical or otherwise, within acceptable limits, and therefore avoid the propagation of disturbances. It is also governed by a logic aimed at reducing the complexity of a given situation. Finally, it is a way of managing individual resources.’ (p. 35)

Several ideas are included in this definition: assessment of the development of the situation, mental simulation, and anchoring in both temporality and action. Two important aspects should be stressed: the teleonomic aspect, as anticipation only makes sense in light of a general purpose; and the cognitive aspect, as the process is also governed by the need to reduce the load and complexity of the environment. It is therefore possible to anticipate without planning.

By contrast, planning cannot be detached from anticipation. Hoc (1987) defined planning as ‘the development and/or implementation of plans’ (p. 68). In other words, planning consists of building a simplified schematic representation of a task, breaking it down into sub-goals, the aim of this being both to save cognitive resources and to be action-oriented: planning is teleonomic, i.e. it is directly linked to the achievement of a predefined end. As a result, according to Amalberti (1995), if the purpose of planning is to develop an executable plan which is compatible with the operator’s skills, the purpose of anticipating is precisely to test the validity of such a plan. After pointing out the central position of the concept of plan, this study will focus on the means of preparing and implementing plans.

About the concept of plan

Developing plans

Hoc (1987) defined the concept of plan as ‘a schematic and/or hierarchical representation which is likely to guide the activity’. The terms ‘schematic’ and ‘hierarchical’ are of particular importance: they mean that the representation is defined at a low level of detail and that a strategy of successive refinements is needed. If, in Rasmussen’s decomposition hierarchy (Rasmussen, 1986), the plan is defined at a higher level of detail than the implementation of the activity, then it can be hierarchical as well: this will bring to light different levels in the plan’s structure, and the relationship existing between such levels. This may prove useful when the implementing rules of a given procedure are linked to those of a sub-procedure to be performed later. Thus, planning also consists of sequencing operations before performing them.

Amalberti (2001) highlighted a fundamental limitation in dynamic contexts: the processes of planning and refining a representation are to last until no credible solutions are found or as long as the cost of implementing the representation is unacceptably high. O'Hara & Payne (1998, 1999) brought up the 'stopping condition': the most important point consists of defining a meta-plan relying on adequacy criteria (minimum acceptable requirements, objectives, costs) and defining the difficulties that need to be avoided or addressed. It is not necessary to refine the current representation indefinitely with unsteady elements or if the defined solution is strong enough with regard to the acceptable requirements.

In the context of photographic reconnaissance in single-seater fighter aircraft, Amalberti (1996) distinguished between expert and novice approaches: expert pilots use prospective procedural planning, whereas novices use a mix of prospective strategies – the ones they are taught – and retrospective strategies in order to manage realistic implementations considering their lack of expertise. As a result, experts are faster at developing plans for they possess metaknowledge which allows them to use already memorised parts of plans. This study will then focus on the structure and main features of the plan.

The plan and related concepts

The first main feature of the plan has been outlined above: it is fundamentally schematic. Its second main feature is that of being oriented towards anticipation. Several cognitive psychology concepts related to the plan deal with the latter feature. The notion of 'scheme' introduced by Piaget (1952) goes further in this direction: any actions taken in the real world would follow a predetermined scheme adapted to the current situation.

A direct consequence of this postulate is that the notion of expectation about the development of the situation must be added to our view of the plan. Vergnaud (1985) insisted on the relationship between the scheme and the real world: he put the stress on the necessary isomorphism between the plan and the real world, which is validated by the performance of the plan. Denecker (1999) postulated that the scheme organises the subject's behaviour by cutting the real world down into objects. The resulting representation may be the subject of operations, inferences, rules of action, or even predictions and expectations.

Regarding Bartlett's concept of 'schema' (Bartlett, 1932), Denecker (1999) raised several issues relevant to the debate:

- it is an unconscious mental structure produced from past experience;
- it stores, in the long-term memory, a set of active knowledge structures instead of passive images;
- it is a reconstruction, not a copy, of the past.

Bobrow & Norman (1975) hypothesised that the schema is not a definite structure, and that it links the variables and the constraints over them. Such variables are singled out during the performance of the plan thanks to environmental clues which shape the implementation of the plan.

In short, as pointed out earlier, the plan is hierarchical and it is also fundamentally deficient. Thanks to its structure, operations can be performed on the plan itself, and this feature is a way of saving resources. Next, the accuracy of this representation needs to be reviewed.

Plans, time constraints and implementation

Amalberti (1996) pointed out the role of time constraints in the search for a compromise between the cost of plan development and the degree of accuracy in guidance, i.e. the tolerance to variations linked to possible hazards. In less dynamic systems, the action plan is usually maintained at a low level of detail and its interpretation and the ultimate choices of implementation are made at the very moment of performance of the plan (de Keyser & van Daele, 1986); besides, the preparation of solutions is not given much attention. In more dynamic (i.e. fast) processes, such as fighter aircraft, the pilot needs to arm himself against the lack of time and resources in order to develop new plans or solve unforeseen problems. The solution lies in developing more detailed and more guiding plans, and preparing responses to a limited number of likely incidents. It is a bet, weighted by the pilot's experience and the context of action.

A commercial-transport-aircraft flight is a temporally intermediate situation. Preparing to incidents is no longer part of the initial briefing but is contemplated on a sequence-by-sequence basis during the entire flight. Wickens (2002) defined four kinds of tasks to be undertaken while flying an aircraft: aviating, navigating, communication, and systems management. All of these tasks need to be performed, and this is the reason why pilots, however expert they may be, rely on checklists. Anticipating can therefore consist of preparing responses to a list of likely events. This example is in line with Rasmussen's SRK model (Rasmussen, 1983): when facing a complex situation requiring implementation of knowledge to construct a response, anticipation makes it possible to develop a routine that is ready to use when appropriate. Amalberti (1996) developed the idea further: the operator avoids, as much as possible, situations which

prove complex with regard to his own expertise, and he gets ready for unavoidable situations by organising his responses beforehand.

Nevertheless, a few important limitations should be noted: checklists can by no means assist the pilot in performing multiple tasks simultaneously, nor do they address – by definition – the unexpected. Moreover, it is often not possible to draw up a list of tasks related to procedural knowledge, however vital this knowledge may be for the appropriate performance of the tasks (Wickens, 2002).

As discussed earlier, anticipation is the most important tool for implementing plans, the details and objectives of which depend on expertise. Deviations from plans are a perfect example of this (Amalberti, 1996). For expert pilots, deviations are systematic and repetitive but limited in their value. Though accurate, the framework provided by plans allows sufficient latitude for interpretation during implementation. Experts therefore prefer procedural, action-oriented plans in order to save cognitive resources. For novice pilots, deviations are exceptional but of greater magnitude: they are not the result of procedural interpretation but of a will to protect the initial plan and apply the responses prepared during planning. An example is the case of young pilots who delay their actions intentionally in order to anticipate a subsequent situation to which they may have to react by increasing their speed.

Whereas planning consists of developing plans, anticipation works toward their validation. After analysing the structure of plans, the mechanisms of anticipation will now be reviewed.

Anticipation

In the context of driving a car, Tanida & Pöppel (2006) and Mundutéguy & Darses (2007) offered a generalisation of the principle of reafference proposed by von Holst & Mittelstaedt (1950) to explain how anticipation works: a plan of the situation is activated from a pattern of sensory environmental clues. The expectation component of the plan was described above. An efferent copy of this component is produced, which can be compared with the real world. The plan is, in itself, an active means of recognition: it guides and directs the search for information in order to validate itself (Amalberti, 1996). A plan is validated when its entire content can be particularised to the situation; but some mechanisms make it possible to fill any gaps with acceptable default values.

The teleonomic component of the plan was described above: it is action-oriented and directed towards a specific purpose. This component of the plan is subject to two forms of monitoring (Amalberti, 1996): external monitoring – involving the physical process and the situation –, and internal monitoring – involving the cognitive actor of the process. In case of problem (negative outcome in self-assessment of the performance), thanks to internal monitoring, the degree of cognitive investment can be increased in order to adjust the selected mental model: enrichment, adjustment, or even construction of a new solution. This metacognitive monitoring is also in charge of arbitrating the following processes: intensity, priority, stopping.

Depending on the available timeframe, this monitoring offers different strategies: in the short term, the operator first and foremost tends to deal with ongoing tasks, using heuristics and various measurements (predictability, time constraints, etc.) to be able to perform multiple tasks at the same time while minimising risks; in the long

term, the Cognitive Architecture of Dynamic Control model described by Hoc & Amalberti (1994) illustrates the possibility, for the operator, to open several cognitive loops simultaneously, which project into different levels of temporal depth.

The levels of performance, models and anticipations are continually self-assessed. Because of his cognitive limitations, the operator has to achieve a compromise with regard to the possible corrections; this compromise is based on the resources available and on the various requirements related to the task. Three loops take place in three different temporalities – i.e. three distinct ambitions of corrections – from automatic control to the complete reconsideration of the current representation. As set out earlier, the attentional supervisor is responsible for the possible corrections and for any local changes in the level of action control.

At this stage, it appears that a major way of assisting pilots in the anticipation process consists of helping them choosing their plans. This may be considered as a further argument in favour of our approach: the operator remains at the centre of the decision loop. Any additional information that may be provided to the operator would help him construct or complete his representation but would not, under any circumstances, intend to replace it.

Conclusion

As shown throughout this study, the plan plays a central role in both the cognitive-resource-saving process and the anticipation process. In order to design a tool assisting operators in the anticipation process, it is relevant to tackle process modelling starting from the plan itself. This literature review pointed out the hierarchical and fundamentally deficient structure of the plan, as well as its activation through the

detection of a pattern of environmental clues. Defining an activation framework can be a way of designing such a tool.

A last important aspect is about the distance between the initial plan and the plan actually implemented. Two subsidiary questions emerge:

- How to measure the cognitive cost of challenging an established plan, or even wholly or partially rebuilding it, when faced to contradictory environmental elements (unfulfilled expectations)?
- How to handle tolerance to deviations from the initial plan (are errors controlled or not)?

These questions will be the subject of more detailed investigations in future works.

References

- Amalberti, R. (1995). Anticipation. In M. de Montmollin (Ed.), *Vocabulaire de l'Ergonomie*: Octares.
- Amalberti, R. (1996). *La conduite de systèmes à risques*. Paris: Presses Universitaires de France.
- Amalberti, R. (2001). La maîtrise des situations dynamiques. *Psychologie française*, 46(2), 107-118.
- Bartlett, F. C. (1932). *Remembering: A Study in Experimental and Social Psychology*: Cambridge University Press.
- Bobrow, D., & Norman, D. (1975). Some Principles of Memory Schemata. In *Representation and Understanding: Studies in Cognitive Science* (Bobrow Daniel, Collins Allen H. ed., pp. 131-150). New York: Academic Press.
- Cellier, J. (1996). Exigences et gestion temporelle dans les environnements dynamiques. In *La gestion du temps dans les environnements dynamiques* (pp. 20-48). Paris: Presses Universitaires de France.
- de Keyser, V., & van Daele, A. (1986). Fiabilité humaine, sécurité, automation, le cas des conducteurs de tours à commande numérique ou manuelle. *Le Travail Humain*, 49, 117-136.

- Denecker, P. (1999). Les composantes symboliques et subsymboliques de l'anticipation dans la gestion des situations dynamiques. *Le Travail Humain*, 62(4), 363-385.
- Hoc, J. (1987). *Psychologie cognitive de la planification*: Presses Universitaires de Grenoble.
- Hoc, J., & Amalberti, R. (1994). Diagnostic et prise de décision dans les situations dynamiques. *Psychologie française*, 39(2), 177-192.
- Minkowski, E. (1968). *Le temps vécu*: Delachaux et Niestlé.
- Mundutéguy, C., & Darses, F. (2007). Perception et anticipation du comportement d'autrui en situation simulée de conduite automobile. In *Le travail humain* (Vol. 70, pp. 32). Paris: Presses Universitaires de France.
- O'Hara, K., & Payne, S. (1998). The Effects of Operator Implementation Cost on Planfulness of Problem Solving and Learning. *Cognitive psychology*, 35(1), 34-70.
- O'Hara, K., & Payne, S. (1999). Planning and the user interface: The effects of lockout time and error recovery cost. *International Journal of Human Computer Studies*, 50(1), 41-60.
- Piaget, J. (1952). *Naissance de l'intelligence chez l'enfant*: International Universities Press.
- Piaget, J. (1975). *L'équilibration des structures cognitives : problème central du développement*. Paris: Presses Universitaires de France.
- Piaget, J., & Buscaglia, M. (1967). *Biologie et connaissance : essai sur les relations entre les régulations organiques et les processus cognitifs*: Gallimard Paris.
- Rasmussen, J. (1983). Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE transactions on systems, man, and cybernetics*, 13(3), 257-266.
- Rosen, R. (1985). *Anticipatory systems: philosophical, mathematical, and methodological foundations*: Pergamon.
- Sutter, J. (1983). *L'anticipation*. Paris: Presses Universitaires de France.
- Tanida, K., & Pöppel, E. (2006). A hierarchical model of operational anticipation windows in driving an automobile. *Cognitive Processing*, 7(4), 275-287.
- Vergnaud, G. (1985). Concepts et schèmes dans la théorie opératoire de la représentation. *Psychologie française*, 30(3-4), 245-251.
- von Holst, E., & Mittelstaedt, H. (1950). Das reafferenzprinzip. *Naturwissenschaften*, 37, 464-476.

Wickens, C. D. (2002). Situation Awareness and Workload in Aviation. *Current Directions in Psychological Science*, 11(4), 128-133.